BIOCLIMATIC CHANGES IN WESTERN AUSTRALIA

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A considerable amount of material has become available on the subject of climatic changes. Lysgaard (1949) quotes some 500 titles in his bibliography, and more publications of local importance could be added. It is a generally accepted fact that climate is gradually changing, and it is widely believed that the change is in the nature of an oscillation. The changes ascertained so far are particularly noticeable in the Northern Hemisphere, where there has been a rise in temperature and an increased frequency of maritime air masses, with a consequent increase in cloudiness and rainfall.

Much has been written on the climates of the past and the way they may have affected plant and animal life. The symposium published by the Geological Society of America (1949) might be quoted for the Northern Hemisphere, and the several bibliographies it contains may be used for further reference. For Australia the pioneer work is that of Herbert (1928), Wood (1930) and Crocker and Wood (1947) as far as plants are concerned. As to animal life, an analysis of past climates is given by Gentilli (1949).

Very little work, however, has been done on the biological consequences of present-day climatic changes, although many changes in the geographical occurrence of species have been noticed without being specifically attributed to any climatic cause. The work of Kalela (1949) could be quoted for Finland, a region where recent climatic changes have been well marked, and of great consequence to animal life.

The Australian writers quoted above have mentioned the effect of climatic changes on Australian plant and animal life, especially with regard to the "Great Aridity" of the early Recent, perhaps some 10,000 years ago. No attempt has been made so far to assess the exact amount of climatic change required in order to cause any significant change in the biological environment.

Prescott (1946, 1949) quotes the following critical values of $\frac{P}{E^{0.75}}$ where P is the total monthly precipitation and E the total monthly evaporation:

For the break of season	0.40
To start and maintain growth after break of drought	0.54
Before drainage begins in gauges	0.74
For vegetation of low transpiration or for start of drainage through bare soil	0.08
For vegetation of average transpiration or for balance between water intake and loss in catchment areas	1.20
For balance between water intake and loss in field vegetation	1.30 to 1.50
For vegetation of high transpiration	1.60
For rice fields	2.00

Because of the difficulty of measuring evaporation, Thornthwaite (1948) evolved a method for the computation of the combined evaporation from vegetated soil and transpiration from plants, and suggested the term evapo-transpiration for this combined water-loss. A climatic analysis of Western Australia according

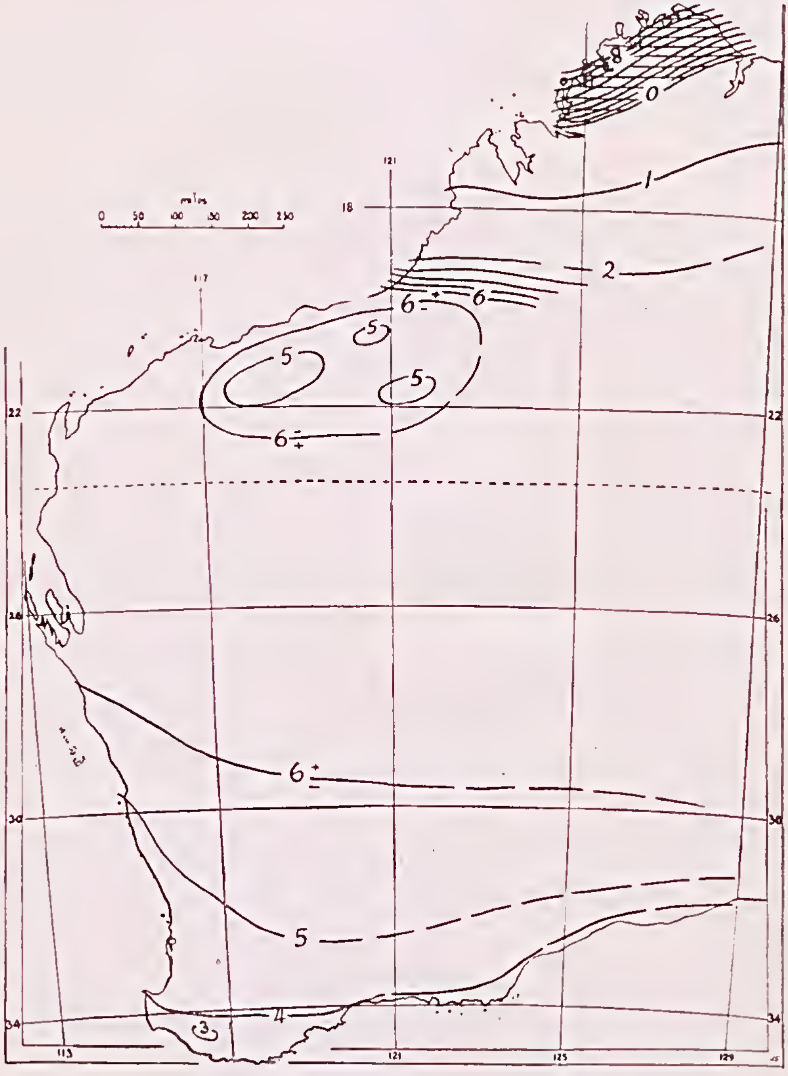

Fig. 1.—ADDITIONAL RAINFALL NEEDED to support vegetation of average transpiration during the month of January, expressed in inches. The shaded area has sufficient rainfall on the average.

to this method was given by Gentilli (1948), who later gave a table of monthly climatic values computed according to a modified formula which makes Prescott's and Thornthwaite's formulae comparable (Gentilli, 1950).

It is possible to compute the amount of rain which must be

Fig. 2.—ADDITIONAL RAINFALL NEEDED to support vegetation of average transpiration during the month of April, expressed in inches. The small area in the South-west usually gets sufficient rainfall; most of the southern region needs an additional inch or two.

added to or subtracted from the total monthly rainfall in order to reach a balance between outgoing water (evapo-transpiration) and incoming water (rainfall). This balanced condition corresponds to 1.20 in the list of critical values given above, i.e., to the normal balance required by vegetation of average transpiration.

Figs. 1 to 4 show the amount of additional rainfall needed during the respective month in order to reach the optimum condition for vegetation of average transpiration, assuming that optimum conditions prevail in the remaining months in each case, i.e., that there is no carryover of moisture from one month into the following ones.

It will be seen that January has more than the amount of water required only in the extreme north of Western Australia. The rainfall of the northern grasslands falls some 2 inches short of the optimum. That of the north-western soft-spinifex grasslands falls some 5 to 6 inches short. The arid region needs over 6 inches in order to reach the optimum. Further south, even the heart of the karri forest needs from 3 to 4 additional inches of rain to reach optimum conditions in January. It is obvious that any foreseeable climatic change is likely to fall far short of the amount needed to change the Western Australian January into a humid month, with the exception of the northern region, as far as Broome and Hall's Creek, where only 1 to 2 more inches would transform the landscape.

In April the karri forest region has already reached optimum conditions, and the jarrah forest needs less than 1 additional inch of rain to do the same. Nearly all the region south of latitude 30° S could reach a climatic optimum in April by the addition of less than 2 inches of rain. Larger amounts are needed elsewhere, up to 5 inches in the drier north-west.

During July most of Western Australia reaches or approaches a climatic moisture optimum. The south-eastern forest region actually receives some 6 inches more than the optimum, and the whole area from Sharks Bay to Israelite Bay exceeds the optimum rainfall. An increase of less than 1 inch would be enough to bring the whole of Western Australia except the Kimberley region within the optimum.

Conditions in October resemble those which prevail in April, but the south-western region is slightly better off in October, because of the last rains obtained from travelling fronts. The remainder of Western Australia, because of the autumn tropical cyclones, is better off in April.

These maps show that even small additional amounts of rain may cause widespread changes during some months.

It is also possible to compute the additional amount of rain which is needed to reach hygrostatic balance for the whole year, i.e. the amount of rain which should be added to the average annual total in order to obtain those climatic conditions under which the effect of leaching in the soil is balanced by that of the addition of organic matter. It will be seen from Fig. 5 that very considerable climatic changes would be necessary before the position of the "hygrostatic zero" line moved very far. To bring the

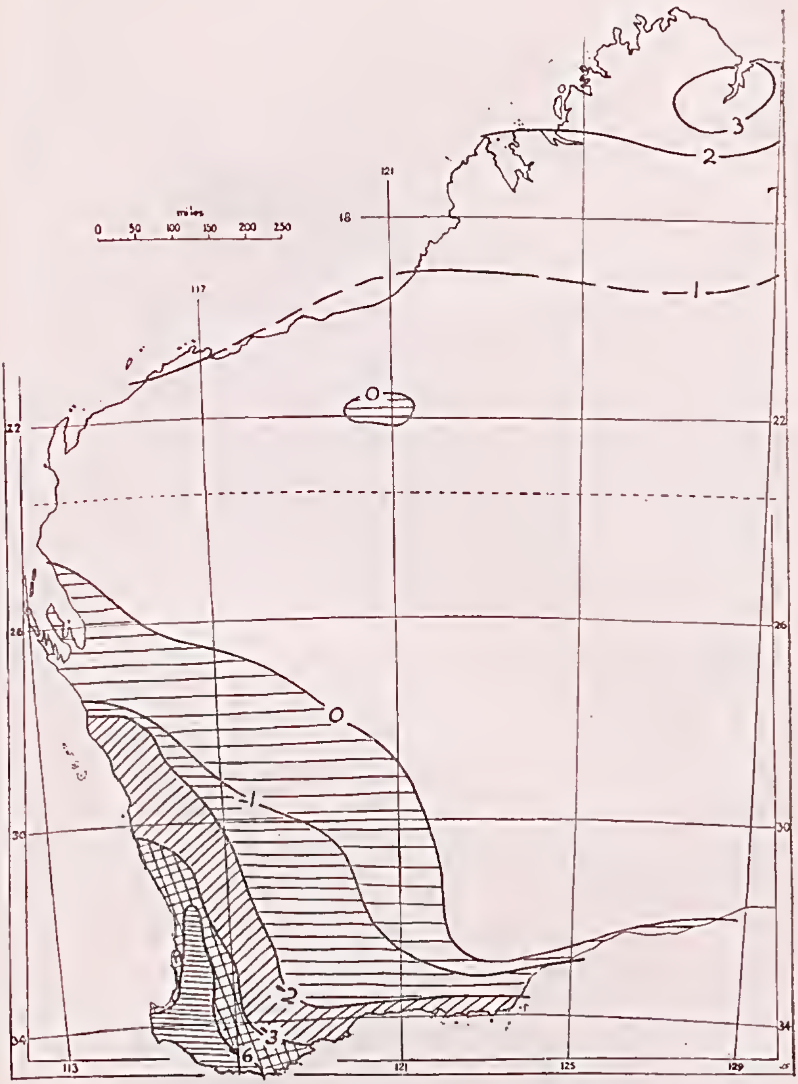

Fig. 3.—ADDITIONAL RAINFALL NEEDED to support vegetation of average transpiration during the month of July, expressed in inches. The shaded areas usually receive sufficient rain for the purpose, so that rain should be decreased in order to reach the minimum required.

"hygrostatic zero" line less than 100 miles further towards the interior than its present position there should be an increase of 20 inches in the annual rainfall. If that happened, the outer edge of the forest would only move some 70 or 80 miles towards the interior.

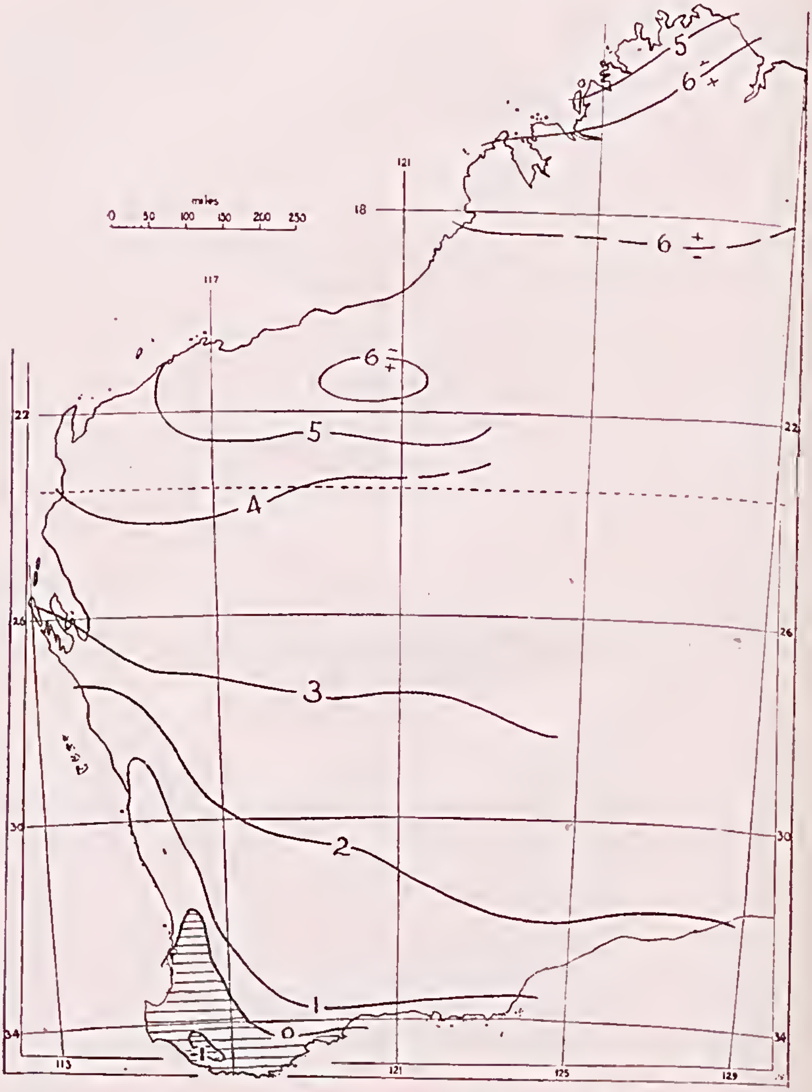

Fig. 4.—ADDITIONAL RAINFALL NEEDED to support vegetation of average transpiration during the month of October, expressed in inches. The great deficiency of rainfall in the Kimberley region stands out very clearly. The last frontal rains make conditions in the South-west nearly adequate.

Writers have stressed the effect of the past "Great Aridity," and it is towards a study of arid changes that research should be directed. Fig. 6 shows some results of this research. The margin of the desert is found at present along the dented line marked 0 on the map. A decrease of only 5 inches in the annual rainfall, if suitably spread throughout the wetter part of the year, would be sufficient to bring the desert margin to where the wandoo woodland is found at present. The semi-arid woodland of mallee and salmon gum would become an expanse of mulga. The various species of mallee and the salmon gum with its associated species would be confined to a narrow belt, less than 100 miles wide, where the wandoo grows at present.

The importance of the South-west as a biological refuge is clearly shown by this map. Even if the average rainfall decreased by 30 inches, the edge of the arid zone could not reach the south-western edge of the plateau, where the denser forests grow at present. The same may be said of the north-western Kimberley area. On the other hand, a decrease of only 5 to 10 inches in the annual rainfall of the Kimberley region would bring the arid zone past Derby and Wyndham.

The semi-arid region which extends over the Hamersley Range and as far east as Nullagine, interrupted by gorges and steep slopes with innumerable microclimates, is now separated from the semi-arid belt of pindan country and Kimberley grassland. An increase of 1 inch or little more in the annual rainfall would create a corridor joining these regions along the littoral, just west of the sandy desert.

The vagueness of the eucalypt-mulga boundary is well understood after a study of this map. An increase of only 1 inch in the total annual rainfall would make the arid edge recede by 100 to 200 miles, probably enabling eucalypts to grow much further inland than at present. The migration of the arid belt between its positions with a 1-inch increase and a 5-inch decrease in the annual rainfall would span a maximum of 500 miles, from latitude 27° S to 33° S. Further west the span is much less, and near Sharks Bay it covers only some 50 miles or so. The area affected is approximately 240,000 square miles.

A more detailed estimate of the areas concerned shows that the arid edge would engulf the following areas for each respective change in the total annual rainfall:

after a decrease of 5 inches, about 120,000 sq. m. in the South-west, over 45,000 sq. m. in the Hamersley-Nullagine region, and some 20,000 sq. m. south of the Kimberley region;

after a further decrease of 5 inches, some 50,000 sq. m. in the South-west and over 100,000 sq. m. in the Kimberley region;

after a further decrease of 10 inches, some 30,000 sq. m. in the South-west and a smaller area in the Kimberley region.

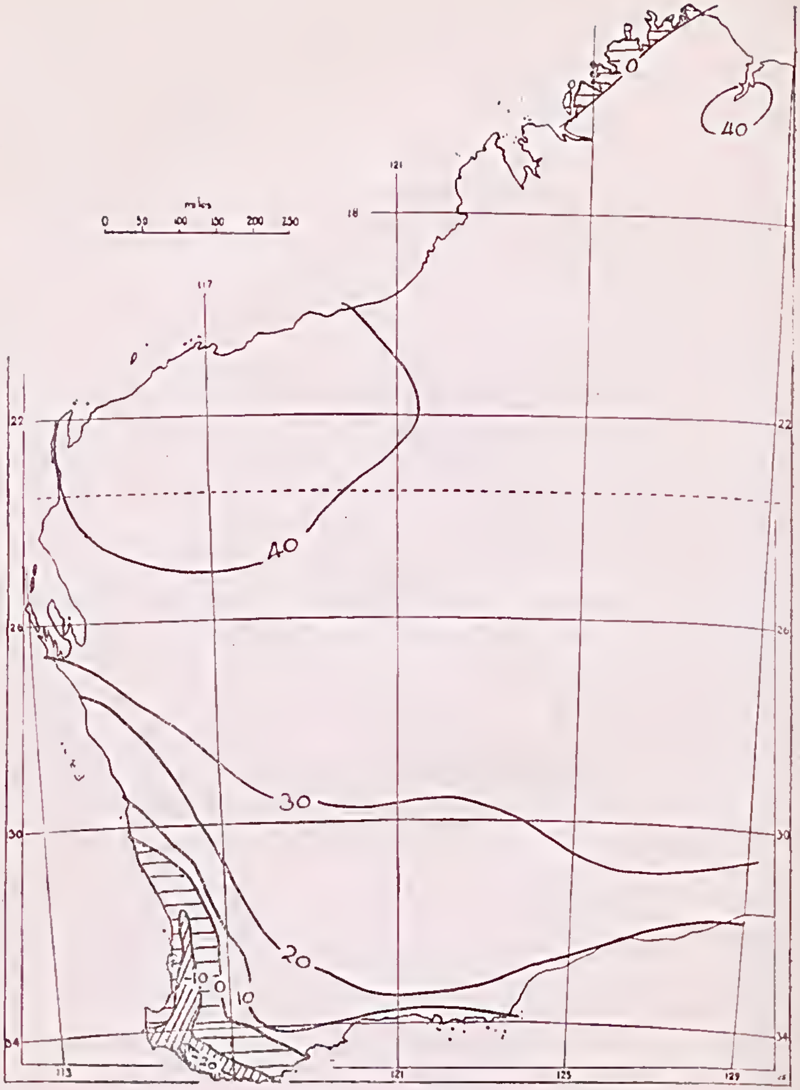

Fig. 5.—ADDITIONAL ANNUAL RAINFALL NEEDED to reach hygrostatic balance (zero), expressed in inches. The very steep climatic gradients of the South-west stand out clearly and contrast with the broad transition zones found further inland. Notice the large area which would need some 40 inches of rain in addition to its present rainfall in order to reach hygrostatic balance (in which case it could support woodland vegetation and develop neutral or slightly acidic soils).

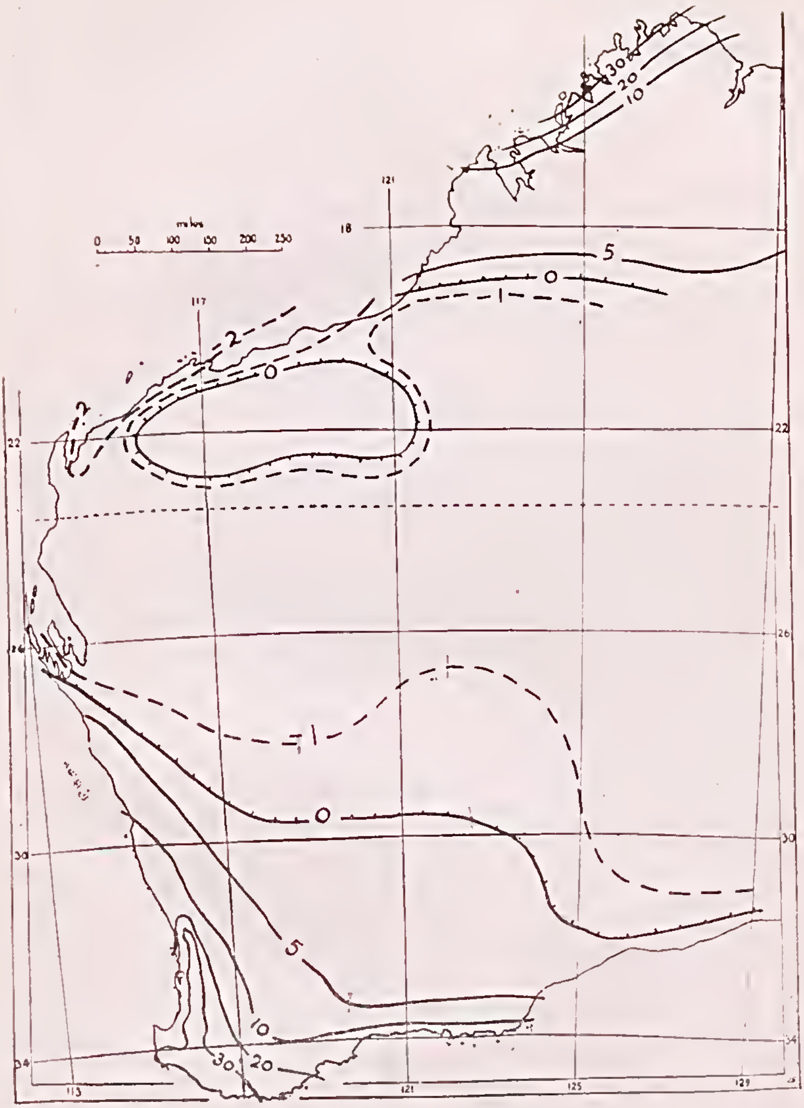

Fig. 6.—POSITION OF THE DESERT MARGIN corresponding to any decrease in the total annual rainfall, expressed in inches. Notice the increasing steepness of the gradient towards the extreme north-west and south-west of the map, and the broad transition zone on both sides of the zero line from Sharks Bay to the Great Australian Bight.

An increase of 1 inch would bring back into the semi-arid zone and outside the arid edge some 120,000 sq. m. of country north of the present mulga-eucalypt boundary.

The Western Australian environment is, therefore, much more deeply affected by movements of the arid margin and by a decrease than by an increase in the rainfall. So far, past biological history seems to bear this out.

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